Intense Stimulated Raman Scattering in CO_2-filled Hollow Core Fiber

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Frequency combs are of constant significant interest for their use in diverse areas of physics ranging from metrology to biomedical and environmental spectroscopy. One of interesting techniques to obtain multi-octave comb-like optical spectra is based on generation of higher-order stimulated Raman scattering (SRS) in a hollow-core photonic crystal fibers (HC-PCFs) filled with hydrogen gas [1]. The ability of these types of fibers to strongly confine together gases and laser pump, while keeping their interaction length over several meters, has allowed to reduce, by six-order of magnitude, the laser power in comparison to previous equivalent techniques using a gas cell, which have required a GW level of peak powers. However, the power threshold to generate intense Stokes and anti-Stokes Raman lines is still in the order of tens of kW [2,3]. Moreover, a main inconvenience of using a hydrogen gas in HC-PCF is a high hydrogen permeability of silica, which requires of using special actions to protect the fiber from gas leakage. To overcome this undesired and destructive issue, in our work we use instead CO_2 gas and we study its Fermi-dyad $\nu_1/2\nu_2$ band through SRS. This Q-branch rovibrational, shifted by 41.64 THz from the pump laser, is of fundamental interest because of its unique extremely narrow spectral width of the order of 300MHz (at FWHM) at around 1 bar of CO_2. Indeed, at the pressure of about few tens of mbar to 1 bar, this band undergoes a strong spectral compression due to combined effects of Dick narrowing and collisional line-mixing. Moreover, although it is well-known that SRS of CO_2 is less efficient that the one of hydrogen, interestingly the Q-branch of CO_2 may exhibit a strong collapse, which makes this band very intense [4].

In our experiment, we used a photonic microcell system from GLOphotonics; Namely, a 3m-long HC-PCF with 30μm of inner core diameter, terminated from both end sides by two gas-fillable cells, that we filled with CO_2 gas with various pressure levels up to 6 bars. As a pump beam we chose a Nd:YAG microchip laser delivering ~1ns pulses at 1064 nm, with the repetition rate of 1kHz.

Figure 1 illustrates the spectrum spontaneously generated by SRS, and covering more than one-octave spectral range from 0.9 up to 2 μm. Remarkably, only 6 bars of CO_2 pressure and 15.5kW of guided peak power have been enough to obtain three Stokes sidebands, with intense first two lines, and one anti-Stokes sideband. Note that at this CO_2 pressure, the quite intense first two Stokes lines can be obtained even at pump power down to 4.5kW and 12kW for the first and second Stokes sidebands, respectively, a lower power level than that required for H_2 at few tens of bars. Moreover, we found that for moderate power of 19kW a first pair of Stokes and anti-Stokes lines can be visible (16dB lower than the pump for the first Stokes wave) even at CO_2 pressure as low as 1 bar. Note also that the Raman sidebands are very narrow, thus preserving the spectral finesse of the pump laser.

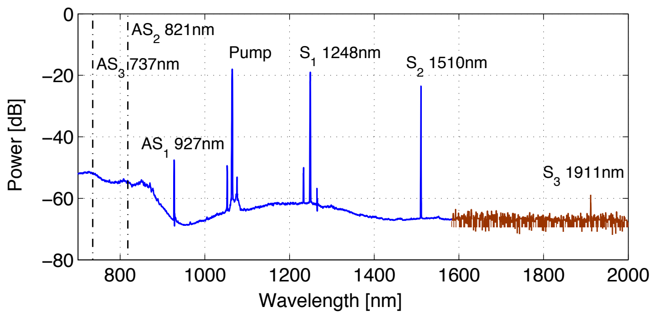

Fig. 1 Experimental spectrum showing a Raman frequency comb generated at 6 bars of CO_2 pressure and 15.5kW of guided peak power. First and second Stokes lines are of ~1.1dB and 5.6dB below the pump. Blue and brown part of the spectrum was measured with different optical spectrum analysers.

Obtained results have a strong potential for application in numerous domains including, for example, development of novel high spectral finesse compact and powerful laser systems at new "exotic" wavelengths, which are not covered by existing gain media.

References

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